TRIBOLOGICAL BEHAVIOR AND SURFACE QUALITY OF POLYMERIC INDUSTRIAL SEALING MATERIALS

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Abstract Tests presented in our research work as an example give look into the wear and friction behaviour of some typical polymer sealing compound (POM, PEEK, PA). The measurements examine above all the effect of surface roughness onto the wear and friction behaviour wear in case of optimal loading relations. We have carried out the test in pin-on –disc system. Based on the test results we have classified the polymers on the basis of wear and friction factors.
Keywords *polymer tribology, sliding seals, surface roughnes, pin on disc*

1. INTRODUCTION

The practical choosing of moving (sliding) seals used in industry takes place in many cases by „ad hoc" manner keeping in view first of all load characteristics (pressure-tighness, mechanical properties). Less attention is given to the tribological factors (wear resistance, friction coefficient) and less data are available, too. It would be important in particular to carry out tribological tests connected with optimal operational parameters (sliding speed, load) which could help the practical selection. These tests also could be generally accepted (standardized) laboratory tests. These use small-scale specimens, which advantage are:

- Simple test set, small loading force, small-scale specimens,
- Environmental characteristics easily set and the costs are low.

The most important tribological questions of the sealing systems belong the material combining (seal-metal surface) and the morphology of sliding surfaces (roughness, geometry).
The technical literature of tribological characteristics of sealing compound is extensive [1-5], but within these few number of sources give account from sliding and wear characteristics of new generation polymer sealing compounds. The main aim of present tests is to give look into wear and sliding friction characteristics between small scale polymer specimens and steels having different surface roughness. We have carried out the laboratory tests by standard pin-on-disc continuously sliding system, the changes to be ensued we have observed with optical method. The results got can contribute to optimizing and widening the possibilities using sealing compounds, too.

2. METHOD

1.1 Materials tested

We have aspired at choosing the material to be tested to be widely used at such places where the wear is significant in sealing technique (for example centering or supporting rings of actuating cylinders). Based on the formers and industrial demand respectively we decided on Polyamid (PA)-types, one modified polyetheretherketone (PEEK) and one polyoxymethylene co-polymer (POM C).
Table 1. contains the materials tested and their important characteristics.

Table 1.

	Polyamide 6.6 (PA 66)	***Polyetheretherketone modified (PEEK mod)***	***Copolymer Polyoxymethylen (POM C)***	***Polyamide 66+teflon (PA 66 TF)***
Density g/cm^3	1,15	1,44	1,41	1,15
Yield stress N/mm^2	85	-	30	60-90
Modulus in tension N/mm^2	3300	-	3000	1600-3500
Application temp. continuous °C	-30 bis 80	250	-50 bis 100	80-100

Shortly on te role of sealing technique of materials tested [6].

- The polyamid 66 is widely used for bearings and in actuating cylinders as supporting-guiding ring, because it’s good abrasive wear resistance remains in dry condition, too. Its use is limited by its heat resistance and its bad dimensional stability.
- The POM C belongs to the acetal groups, it is used as bearing, as guide bush and hydraulic cylinder seal because of it’s good, mineral oil and fuel stability.
- PEEK is an engineering plastic with high pressure heat resistance and it has got suitable resistance against oil and gas. It is used as „U” and „V”-sealing element for piston and valve ring.

Further information can be found on tribological tests with different parameters of the polymers or their versions tested [7-9].

1.2 The test set

The measuring of dry sliding coefficient of polymer/steel sliding pair was carried out on standardized pin-on-disk (ASTM 699-95a) test set. The sketch of the model tested, the cylindrical plymer specimen and metal counter disk with its dimensions can be seen in Fig 1.

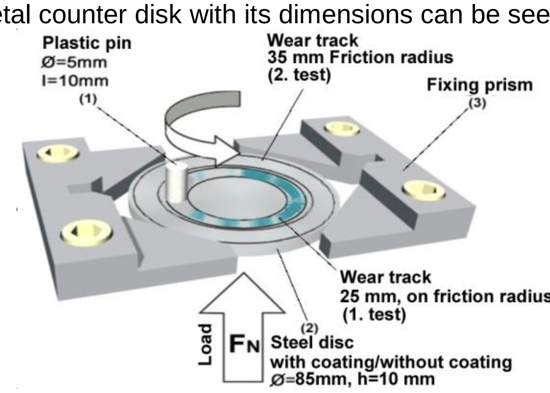


Figure 1. The position and dimension of specimens at pin-on-disk testing system.

The Dynamic Tribotester was the concrete test set developed in our institute, which is also suitable for traditional pin-on-disk tests (Fig 2). To set the revolution an electric motor rotation (5) is used controlled by computer and having encoder, which revolution can be changed infinitely from zero. More information from the test set can be found in technical literature [10-11].

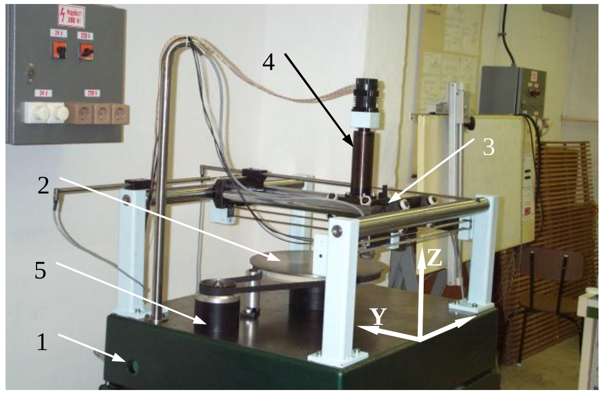


Figure 2. The dynamic tribological test set

Further measuring instruments used at tests:

- surface roughness tester: MITUTOYO Surftest SJ-201 P
- laboratory scale: WA-33 TYP PRL T A13

Cleaning appliances, materials used at tests:

- denaturated alcohol
- hand-drill with rotating plastic cleaning brush

1.3 Test parameters

Decesive standpoints were the followings determining test parameters:

- to indicate wear values first of all, to be estimated according to, comparatively short time measuring (surface roughed properly)
- the deformation of polymers does not influence the wear and friction (small load)
- to keep the heat developing during friction at low value that it can not cause melting from the polymer surface (small sliding speed)

Based on the concrete test parameters, we have set up three measuring grades, which characteristics can be seen in Fig 2. We decided the test time that the friction could reach into the stabile section at all types of material and appreciable material transfer processes could be developed.

Table 2.

TEST PARAMETERS	I. grade (rough)	II. grade (middle)	III. grade (smooth)
Plate/disc R_z surface roughness, [μm]	50-80	-	20-60
Test time, t [h]	1,5		
Load, P [MPa]	0,4-0,6		
Sliding speed, v [m/s]	0,05		
Relatíve humidity, RH [%]	50		
Ambient temperature, T [°C]	25		
Frictional radius, r [mm]	33, 40		

We have carried out the tests on two frictional radiuses at every disc from economicalness consideration. The parameters can be seen in Table 2. in the „Rough” the „Middle” and the „Smooth” test category names referring to the condition of surfaces roughness peaks. The following remarks belong to these:

– The surface of steel disc used as frictional reverse counterpart was machined by shaping in order to reach the proper roughness, we have marked surface with „rough” name referring to the sharp roughness peaks.
– The wear tests were carried out on different frictional radiuses (25 and 35 mm) of the steel disk in three groups successively with four different types of polymer in each group

- At the tests of third group already the wear of roughness peaks belong to the „smooth" category
- The second category means the „middle" surface in reference to the „rough" and „smooth" surfaces

Determining the surface roughness was carried out with needle surface roughness tester (MITUTOYO).

3. DISCUSSION

The figures 4, 5, 6 and 7 show the column diagrams summarizing the test results. The materials tested (PA 66, PA66 TF, POM C, PEEK mod) can be seen in all figures in the same sequence. Three columns can be seen at each material also in similar sequence; the first with „rough" then with „middle", finally with „smooth" category results.

3.1 The categories tested and the comparison of polymers from wear viewpoint

We have determined the specimens wear during tests equally with weight measuring and also continuous dimensional change (length reduction) measuring during measuring. The two methods independent from one another in well visible manner, establish identical wear sequences beside suitable correlation among materials tested.

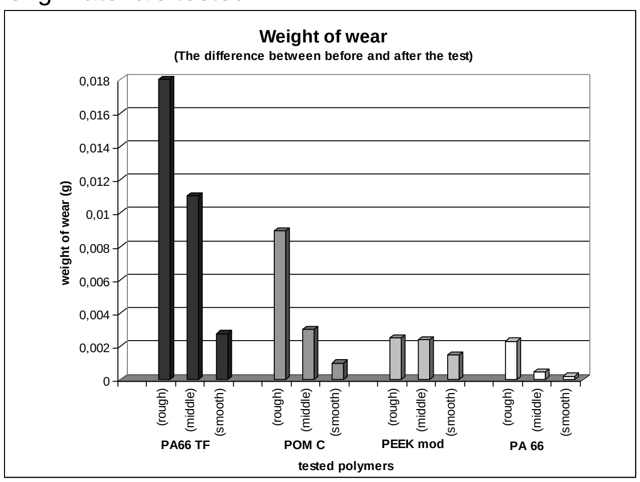


Figure 3. Summed up results of different weight of worn material results

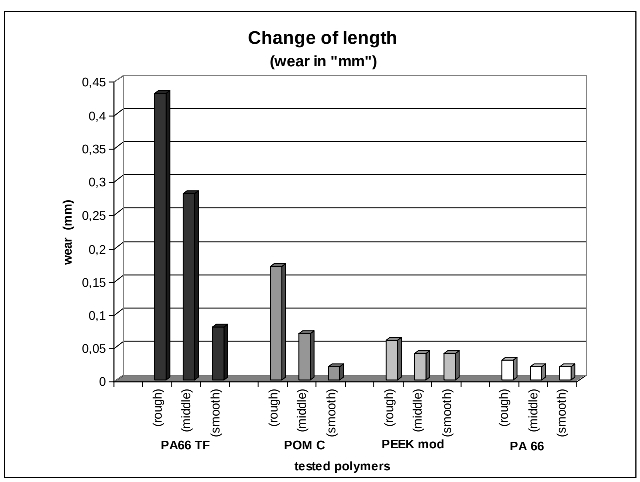


Figure 4. Summed up results of different specimens change of length results

Considerable wear at „PA66 TF" and „POM C"-polymers can be established because of strong cutting effect at test group having „rough" surface roughness peaks. The „PA 66" (See Fig.5) and „PEEK mod" polymer showed substantially lower wear.

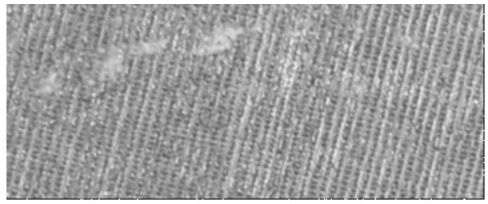


Figure 5. PA 6.6-polymer insignificant wear track on „rough" surface.

We have got essentially more favourable wear values at test group having „middle" surface roughness peaks compared with „rough" category group. It can be probable that the cutting effect reduced to a large extent of the slightly worn (middle) roughness peaks caused this favourable wear value. Among the other polymers the „PA 66" and the „PEEK mod" are the most favourable.
In case of test group of „smooth" surface roughness peaks also the PA 66 polymer showed the smallest wear, but here the POM C-polymer is already in the second place.

3.2 Comparing the categories tested and polymers considering the friction coefficient and friction temperature

Determining the friction coefficient takes place through the measuring of the friction force with the help of specimen holder installed with strain gauges (fig. 2.) The friction coefficient results got can be seen in Fig.6. The column heights mark the dynamic, the stars over them mark the values of static friction coefficient.

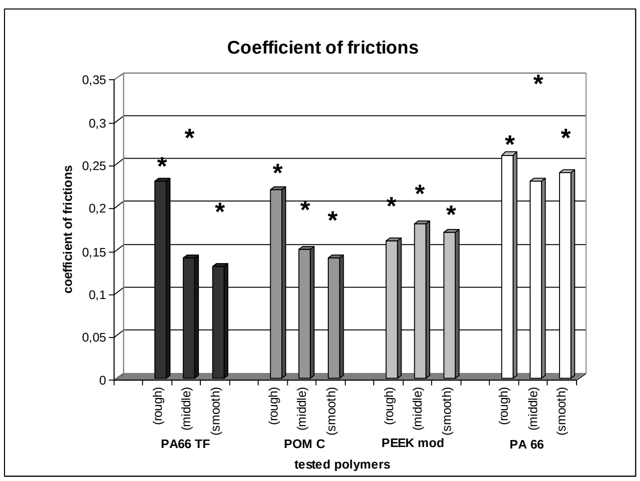


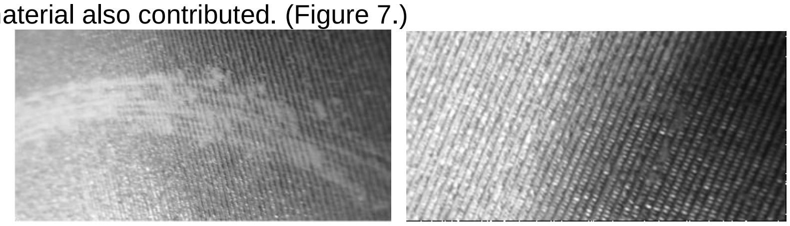
Fig. 6. Values of friction coefficient of polymers tested at different roughnesses

The friction results show constracted order of rank with the wear results. The PA66-polymer shows the largest but almost the same friction on all three surfaces. The PEEK-polymer changes its friction only slightly in the function of surface roughness similarly to the previous polymer however the values are lower contrary to that.
In case of PA66 TF and POM C polymers the friction coefficient changes essentially as a results of surface roughness and the extensive wear results in lower friction.
During tests we have also measured continuously the developed heat in the friction zone. We couldn't indicate significant temperature rise and significant differences because of the small loads and relative large masses and dimensions. Therefore it can be follow up that rougher surface qualities produces a little higher temperature at all materials tested. This results from the values of higher friction coefficient belong to rougher surface.

4. CONCLUSIONS

The following conclusions can be drawn up based on tests carried out:

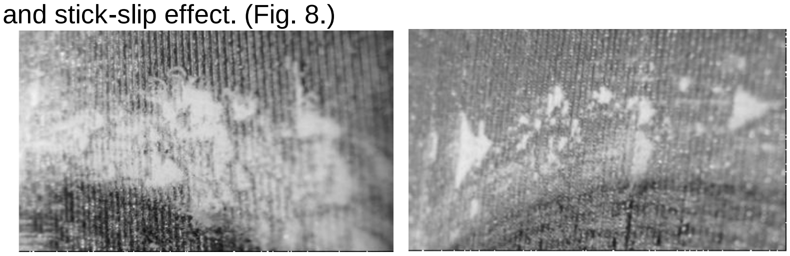
- The PA66 polymer had the most favourable wear resistance in all three categories and beside this the POM-C polymer already on wearing-in surfaces.
- The PA66 TF polymer suffered the largest wear in all three categories.
- The effect of different roughness-peaks influenced only slightly the "PEEK mod" polymer wear.
- The effect of different roughness-peaks influenced in a great extent the POM C and the PA66 TF polymers wear, at the same time in case of PEEK mod. polymer did not cause significant changes.
- The wear characteristics do not mean definitely the favourable values of friction coefficients. It can be probable that to the value of lower friction coefficient of materials with larger wear (PA 66 TF, POMC) the replenisher effect of surface roughness of the worn material also contributed. (Figure 7.)



a.) Rough b.) Smooth

Figure 7. The POMC-polymer wear tracks on rough and smooth surfaces.

- The greater surface roughness helps to get the solid lubricant to the surface, which in case of PA66 TF-polymer brings about PTFE-film development which significantly reduces friction and stick-slip effect. (Fig. 8.)



a.) Rough b.) Smooth

Figure 8. The PA66 TF-polymer wear tracks on rough and smooth surfaces

The results of tribological tests are system-dependent so they do not provide generalization and absolute designing data. They convey useful information on purpose to relative comparison.

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